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Global Public Bads and Two Types of Policy Instruments*

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Abstract

Global environmental problems, such as climate change and deforestation, are often referred to as "global public bads." In this paper, we investigate an international transfer of factor of production how international transfers of production factors either create or reduce public bads. We also study how welfare levels are affected when each government in the transfers adopts a non-cooperative policy to improve environmental quality. There are various ways to mitigate the negative externalities arising from public bads. Our study considers two types of policy instruments: environmental conservation and pollution abatement. In the former, the government restricts the use of resources employed during production. In the latter, the government produces the goods and services necessary to mitigate the negative effects induced by public bads. We show that the effects of transfers on welfare levels and on the amount of global public bads depend on the environmental policy that the government adopts. The second neutrality theorem by Shibata (2003) is particularly valid under the environmental conservation policy, while the possibility of the transfer paradox is not excluded under the pollution abatement policy.

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1 Introduction

Growing concerns over global environmental problems such as climate change and deforestation has increasingly been brought under scrutiny the way in which developed countries lend financial assistance to developing countries. Assistance to developing country is intended not only to improve the welfare of a recipient country but also to reduce global public bads: the negative externalities that may arise from economic activities such as production or consumption.[1]

In this paper, we investigate the effects of transfer of factor of production on the total amount of public bads and the level of welfare when a non-cooperative policy is adopted in order to improve the environmental conditions. This work considers two types of policy instruments that governments may adopt in an attempt to solve environmental problems: an environmental conservation policy and a pollution abatement policy. We show that the effects of transfers on the welfare and on the amount of global public goods depend on the type of environmental policy that each government adopts.

In the field of international economics, much of the existing literature focuses on whether or not international assistance can reduce the amount of public bads and if it may improve welfare in Pareto's sense. Chao and Yu (1999) have argued that tied aid to environmental clean-up can lead to Pareto-improving. Naito (2003) has argued that Pareto-improving is possible by untied aid if the marginal propensity to consume the polluting good in the donor country is sufficiently larger than in the recipient country. Hatzipanayotou et al. (2002) have considered a model in which a recipient country emitting cross-border pollution mitigates the damage using emission tax and public abatement policies. They have argued that an increase in the donor's perceived rate of cross-border pollution in fact reduces emission levels.

Our paper differs from the existing literature in that we consider two types of policy instruments that may reduce the quantity of public bads. In Naito (2003), the provision of public goods was not considered. In the sutdies of Chao and Yu (1999) and Hatzipanayotou et al. (2002), the government can use two policy devices, namely, the emission tax and the public goods provision, to help abate pollution. We do not consider the effect of the emission tax here. Instead, we consider two types of policy: environmental conservation and publicly provided pollution abatement. In the former, the government restricts the use of resources employed during production: this policy is likely to be adopted in developing countries due to their lack of technology.[2] In the latter, the government produces the goods and services necessary to mitigate the negative effects incurred by public bads. In many developed countries, the public sector provides services such as environmental clean-up, and supports R&D activities to reduce the pollution emission.

Although the analysis mentioned above (e.g. Chao and Yu, 1999; Naito, 2003) suggests the possibilities of a Pareto-improving transfer, Warr (1983) states that in the context of the voluntary provision of public goods, the total provision of public goods is independent of distribution of wealth. Shibata (2003a, 2003b) stresses that most public goods are supplied to mitigate the negative externalities arising from economic activities such as production and consumption. In this circumstance, he states that the total provision of public goods is independent not only of distribution of wealth but also of total quantity of wealth: this is

[1] For example, see Shibata (2003a), Shitovitz and Spiegel (2003), and Ihori and Shibata (2004).

[2] For example, in China, the farmland reforestation plan was launched in 1999. It has so far converted 24.3 million hectares of fragile farmland on hillsides into forests (Peoples Daily Online, Oct. 11. 2007. http://english.people.com.cn).

sometimes referred to as the second neutrality theorem. Furhermore, Ihori and Shibata (2006) have illustrated the possibility of immiserizing growth in the presence of a non-contributor. Ono (1998) has derived conditions under which international income transfer brings the Pareto improvement in the presence of a non-contributor.

In this paper, we reconsider Shibata's result (2003a) by developing a model that consists of two small countries in which two tradable goods are produced using two primary production factors. In the standard model of the voluntary provision of public goods (e.g. Bergstrom et al., 1986; Andreoni, 1988), it is assumed that each agent can convert one unit of wealth into a fixed amount of private goods, and that the marginal cost of public goods provision is constant. In this senario, the transfer that takes the form of factor of production is indistinguishable from that which takes the form of the final goods. When we consider the international transfers, it should be noted that the bulk of foreign assistance is used for the capital formation, as pointed out by Yano and Nugent (1999). Hence, we concentrate our attention to the transfer that takes the form of the factor of production in the presence of global public bads. As discussed in Brakman and van Marrewijk (1998), the international transfer of the factor of production has a supply effect known as the Rybczynski effect as well as an income effect that appears in the transfer of final goods.[3]

In addition, we assume that global public bads have a harmful effect on production: for example, climate change may seriously affect agricultural production. Takarada (2005) has developed a model with global public bads that lower productivity in one industry and analyzes the welfare effects of technology transfer in the other. In this paper, it is assumed that global public bads have a negative effect on the two private sectors to varying degrees.

Our main results can be summarized as follows. First, when any government adopts an environmental conservation policy, Shibata's second neutrality theorem is valid under certain conditions. Hence, a Pareto-improving transfer is impossible. Second, as opposed to environmental conservation policy, the transfers of primary factors of production between the countries that adopt environmental clean-up policies may be Pareto-improving. At the same time, we cannot exclude the possibility of a transfer-paradox. Lastly, the transfer of primary factors of production from a country that adopts an environmental conservation policy to other countries that adopt environmental clean-up policies may enhance welfare in the terms of Pareto.

The remainder of this paper is organized as follows. In Section 2 we present an extended version of the Hecksher-Ohlin model with public inputs developed by Abe (1990). Section 3 examines the effects of the transfer of primary factors of production on welfare and the total amount of public bads. Section 4 is the final section and concludes with remarks.

2 The Model

Our analytical framework is a small country model of international trade with spill-over public bads in which two countries labeled as A and B produce two tradable private goods. Each country contains two fixed primary factors of production, labeled as 1 and 2. Factor endowments in country J are denoted by $v^J = [v_1^J, v_2^J]$.[4] The government uses primary factors

[3] Michael and van Marrewijk (1998), Yano and Nugent (1999), and Schweinberger (2002) have also considered the effects of foreign aid taking the form of the factor of production.

[4] To simplify the notation in mathematics, we do not make distinction between vector and scalar variables in description of the model.

according to either resource conservation or clean-up policies. Denoting $v^{JP} = [v_1^{JP}, v_2^{JP}]$ as primary factors available in the private sector, a vector, $v^J - v^{JP}$, is the primary factor used in the public sector.

2.1 Private Goods Production

Production technology in each private sector, which is assumed to be a constant return to scale in primary inputs, is identical across countries. Each private sector minimizes its cost for given factor prices and global public bads. For the sake of analytical simplicity, we specify the unit cost function of the i-th private sector in country J=A,B, as $\hat{c}^i(z, w^J) = a_i(z)c^i(w^J)$, where $w^J \equiv [w_1^J, w_2^J]$ and z denote the vector of the factor prices in country J and the amount of the global public bads, respectively. The effect of public bads on the unit cost is represented by $a_i(z) > 0$, where $a_i'(z) > 0$ and $a_i''(z) \geq 0$ are assumed.

Throughout the paper, we assume that the factor endowments of both countries satisfy the following assumption:

Assumption 1. Two tradable private goods are produced in both countries.

Let good 1 be the numeraire. If both private goods are produced in country J, the competitive market ensures that:

$$a_1(z)c^1(w^J) = 1, \tag{1}$$

and

$$a_2(z)c^2(w^J) = P, \tag{2}$$

where P denotes the fixed world price of non-numeraire goods. Assuming that the two private industries have different factor intensities without reversal, we can write the factor price vector as a function of global public bads and international price.

$$w^J = w^J(z, P). \tag{3}$$

Since production technology is assumed to be identical across countries, the unit cost also becomes the same. Thus, the factor price equalization theorem is valid: $w^A = w^B$. Hereafter, in denoting factor prices, we omit the superscript denoting the country.

Differentiating and manipulating (1) and (2), we obtain the effect of global public bads on the factor prices, $w_z \equiv [\partial w_1/\partial z, \partial w_2/\partial z]$, as follows:

$$w_z = -\frac{1}{z}\begin{bmatrix} \varepsilon_1 w_1 + (\varepsilon_1 - \varepsilon_2)\Lambda^{-1}c_{w2}^1 c^2 \\ \varepsilon_2 w_2 + (\varepsilon_2 - \varepsilon_1)\Lambda^{-1}c_{w1}^2 c^1 \end{bmatrix}, \tag{4}$$

where $c_{wj}^i \equiv \partial c^i/\partial w_j$ and $\Lambda \equiv c_{w1}^1 c_{w2}^2 - c_{w2}^1 c_{w1}^2$. The sign of Λ reflects the difference in factor intensity between two private sectors: if the i-th private sector intensively employs the i-th (j-th) factor, then Λ becomes positive (negative). The elasticity of the negative effects on the production of the i-th sector with respect to public bads are defined by

$$\varepsilon_i(z) \equiv \frac{a_i'(z)}{a_i(z)}z \geq 0.$$

Eq. (4) implies that the price of a production factor which is intensively used in an industry heavily affected by public bads declines unambiguously. If the global public bads symmetrically damage the production of the two sectors, $\varepsilon_1 = \varepsilon_2 = \varepsilon$, then $w_z = -(\varepsilon/z)w < 0$. In what follows, we assume that the negative effects of the public bads vary only slightly between the two industries. Accordingly, both factor prices are negatively affected by public bads.

Assumption 2. An increase in public bads reduces both factor prices.

$$w_z < 0.$$

For given P, v^{JP} and z, the production of private goods in country J can be characterized by a revenue function.

$$R^J = R^J\left(P, z, v^{JP}\right). \tag{5}$$

From the properties of the revenue function, $R^J_v = w$ and $R^J_{vv} = O$ hold. In addition, the marginal loss induced by the public bads is represented by $R^J_z = w_z v^{JP} < 0$, where the last inequality follows from Assumption 2.

The revenue function represents disposable income in the private sector. In order to concentrate our attention on the externality affecting the production, we assume that public bads do not directly affect household utility. In such a situation, the change in the welfare is represented by the change in disposable income. The income-expenditure constraint of country J is represented by $E^J(P, u^J) - R^J(P, z, v^{JP}) = 0$, where $E^J(P, u^J)$ denotes the expenditure function of country J and u^J is the utility of country J. Since we consider only small countries, the change in the welfare is given by $dR^J = E^J_u du^J$.

2.2 Global Public Bads and Government Policy

Global public bads are generated in both countries. Denoting z^J as the net amount of global public bads generated in country J, the total amount of public bads becomes $z = z^A + z^B$. We assume that the amount of the global public bads generated in each country depends on the primary factors used in production. For example, primary factors of production employed during the production emit the pollution, $h^J(v)$, as by-products. We make the following assumption on the pollution-generating function.

Assumption 3. $h^J(v^{JP})$ is identical across the countries and is positively homogeneous and quasi convex in v^{JP}.

2.2.1 Environmental Conservation

When the government adopts an environmental conservation policy, the amount of the public bads generated in country J can be written as follows:

$$z^J = h^J(v^J - v^{JE}), \tag{6}$$

where v^{JE} is the vector of primary factors to be conserved by the government. Thus, $v^{JP} = v^J - v^{JE}$ holds. Inserting (6) into (5), we obtain:

$$R^J = R^J \left[(P, h^J(v^J - v^{JE}) + z^{-J}, v^J - v^{JE} \right], \tag{7}$$

where z^{-J} denotes the public bads generated in the country other than J. Once a target level of public bads in country J, h^{J*}, is decided, the government minimizes its cost. The cost minimization problem can be written as follows:

$$\min_{v^{JE}} w^J v^{JE},$$

subject to

$$h^J \leq h^{J*},$$

and

$$v^{JE} \geq 0.$$

Assuming an interior solution exists, we obtain the first-order condition for cost minimization as $w - \mu h_v^J = 0$ and $h^J \left(v^J - v^{JE} \right) = h^{J*}$, where μ denotes the shadow price of the pollution. From the first-order conditions, we can define the function,

$$S \left(w^*, h^{J*}, v^J \right) \equiv \max \left\{ w \left(v^J - v^{JE} \right) \middle| \, h^J \leq h^{J*}, w = w^*, v^{JE} > 0 \right\}.$$

Because of linear homogeneity of $S(w, h)$, we can write this as $s[w(z, P)]h$. Using homogeneous function properties we obtain

$$s_w(w) h^J = v^J - v^{JE}, \tag{8}$$

and $w s_{ww} = 0$. Inserting (8) into (7), the revenue function becomes:

$$R^J = R^J(P, h^J + z^{-J}, s_w h^J). \tag{9}$$

2.2.2 Environmental Clean-up

In the environmental clean-up policy, the government cannot directly control the resources available in the private sector. Instead of conservation, the government produces public input to mitigate the negative effects from the public bads. Thus, the net amount of the public bads induced by country J is

$$z^J = h^J(v^J) - g^J, \tag{10}$$

where g^J denotes the public input provided in country J. The public input is produced by the constant returns to scale technology. Thus, the unit cost function is defined as follows:

$$c^{Jg}(w) = \min \left\{ w v^{Jg} \middle| \, g^J \geq 1 \right\},$$

where v^{Jg} denotes the primary factors of production used by the government. From the property of the unit cost function, demand for the primary factors of production can be written as $v^{Jg} = c_w^g g^J$.

When the government produces public input to mitigate the negative effects of the public bads, the restricted revenue function can be represented by

$$R^J = R^J \left[P, h \left(v^J \right) - g^J + z^{-J}, v^J - c_w^g g^J \right]. \tag{11}$$

2.3 Remarks

Thus far, we have not explicitly described the government's budget constraints. It is assumed that the governments, which levy lump-sum taxes on their residents, purchase the factors of production at market price. The budget constraints of the government can thus be written as $Tax\ Revenue - wv^{JE} = 0$ in the environmental conservation policy and $Tax\ Revenue - c^g g^J = 0$ in the environmental clean-up policy.

In the next section, we consider the effects when the transfer takes the form of the primary factors of production. It should be noted that the amount of public bads generated in each country does not change if the transfer takes the form of final goods, since the public bads affect production but not consumption, and the terms of trade effects do not appear by the assumption of small country. For example, let us consider an infinitesimal transfer in the form of consumption goods from country A to B by dT. The welfare effects of the transfer then becomes $E_u^A du^A = -dT < 0$ and $E_u^B du^B = dT > 0$.

Even if the transfer is made by the income or final goods, considering the primary factors of production is appropriate in some cases. For example, suppose that the government decides upon the amount of resources to be used in the public sector before those of the production in the private sector. In this case, the government determines the primary factors of production that are available in the private sector.

3 Non-Cooperative Policy Equilibrium and Transfer of Primary Factors

3.1 Environmental Conservation Policy

In this subsection, we consider a situation in which both governments can choose the primary factors of production to be conserved. In it, the revenue function is specified by (9) for J=A and B.

Each government maximizes the net income under the Nash conjecture. Noting that $R_v^J s_{ww} = O$, we can write the first-order condition as follows:

$$\frac{\partial R^J}{\partial h^J} = R_z^J + R_v^J s_w = 0. \tag{12}$$

In (12), the first term of RHS represents the marginal damage resulting from global public bads. The second term is a marginal benefit obtained by allowing for additional public bads. The second-order condition can be written as follows:

$$\Delta^{hJ} \equiv R_{zz}^J + 2R_{zv}^J s_w + R_{zv}^J s_{ww} w_z h^J < 0. \tag{13}$$

From the first-order condition, we obtain the optimal response function as $\phi^{hJ} = \phi^{hJ}(z^{-J}, P)$. The slope of the optimal response function is as follows:

$$\phi_I^{hJ} \equiv \frac{\partial h^J}{\partial z^{-J}} = -1 + \frac{w_z s_w}{\Delta^{hJ}}. \tag{14}$$

Stability of the equilibrium requires $\left|\phi_B^{hA}\phi_A^{hB}\right| < 1$. From Assumption 2 and the second-order condition, it can be seen that $\phi_I^{hJ} > -1$ but its sign is ambiguous. For example, if the damages from the public bads, ε_i, are symmetric among the industries, $\Delta^{hJ} = (1-\gamma-\varepsilon)\left(\varepsilon R^J/z^2\right)$ and

$$\phi_I^{hJ} = -\frac{1-\gamma}{1-\gamma-\varepsilon},$$

where $\gamma \equiv \varepsilon' z/\varepsilon$ denotes the elasticity of ε with respect to the public bads.[5] Noting that the second-order condition implies $1-\gamma-\varepsilon < 0$, we obtain $\phi_I^{hJ} \gtreqless 0 \Leftrightarrow \gamma \lesseqgtr 1$.

From the revenue function, (9), it can be easily seen that the level of resource conservation is independent of the factor endowments. In addition, the factor prices are independent of the factor endowments. Thus, we have the following proposition:

Proposition 1. *Supposing that the two countries adopt a resource conservation policy as a strategic instrument, and that both countries contribute to resource conservation, each country's welfare and the total amount of the public bads are independent of the factor endowments.*

Proposition 1 states that Shibata's second neutrality theorem is valid if both governments adopt the resource conservation policy. The reasoning behind this result is straightforward. Under the conservation policy, since the government can directly control the primary factors used in production, the primary factors available in the private sector, v^{JP}, do not change as long as the initial level of h^J is an optimum in the sense that (12) is fulfilled.[6]

Proposition 1 is still valid even if there are differences in the emission functions between the two countries.[7] On the other hand, as previously considered in Ihori and Shibata (2004), the second neutrality theorem as well as the Warr's theorem does not hold. The theorem also may not hold when the government adopts policies other than conservation.

3.2 Environmental Clean-up Policy

In this subsection, we assume that the government can only choose the level of public inputs. In this situation, the revenue function can be written as (11) for A, B. Noting that $R_v c_w^g = c^g$, we obtain the first-order condition for maximizing the revenue:

$$\frac{\partial R^J}{\partial g^J} = -R_z^J - c^g = 0. \tag{15}$$

The second-order condition can be written as follows:

$$\Delta^{gJ} \equiv R_{zz}^J + 2w_z c_w^g - w_z c_{ww}^g w_z g^J < 0. \tag{16}$$

From the first-order condition, the optimal response function can be written as $\phi^{gJ} = \phi^{gJ}\left(z^{-J}, v^J, P\right)$. The slope of the optimal response function is

$$\phi_I^{gJ} \equiv \frac{\partial g^J}{\partial z^{-J}} = 1 - \frac{w_z c_w^g}{\Delta^{gJ}}. \tag{17}$$

For the system to be locally stable, $\left|\phi_B^{gA}\phi_A^{gB}\right| < 1$ is needed. Under the environmental clean-up policy, the changes in the factor endowments affect the provision of public inputs.

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[5] See Appendix 5.4.

[6] The specification of (6) may be restrictive. Alternatively, if we consider a pollution function with fixed coefficient as $h^J = b_1(v_1^J - v_1^{JE})$, the neutrality holds in v_1 but not v_2.

[7] Indeed, the emission function may differ among countries due to geographical or technological reasons.

Let us consider the effect of the transfer of the primary factors of production on the total amount of the global public bads. Without loss of generality, we consider a transfer from country A to country B by $d\tau$:

$$-dv^A = dv^B = d\tau > 0.$$

Differentiating and stacking (15), we obtain the effects of the changes in the factor endowments on total amount of the public bads.[8]

$$dz = -\frac{\left(1-\phi_A^{gB}\right)\left(1-\phi_B^{gA}\right)}{1-\phi_B^{gA}\phi_A^{gB}}\left(h_v^A - h_v^B\right)d\tau. \tag{18}$$

where $h_v^J \equiv [\partial h^J/\partial v_1, \partial h^J/\partial v_2]$ denotes the marginal emissions from an increase in factor endowments. From the stability condition and the second-order condition, we can verify that $1-\phi_B^{gA}\phi_A^{gB} > 0$, and $1-\phi_I^{gJ} = w_z c_w^g/\Delta^{gJ} > 0$. Noting that $h^J(v^{JP})$ is assumed to be positively homogeneous in v^{JP}, we obtain the following proposition:

Proposition 2. *If the factor endowments ratios, v_2^J/v_1^J, between the two countries, are identical at the initial equilibrium, the total quantity of public bads does not change before and after the transfer.*

Proposition 2 shows that Warr's neutrality theorem does not hold when the factor endowments ratios between the two countries are different. In (18), the term, $h_v^A - h_v^B$, corresponds to the productivity differential in the literature of voluntary provision of public goods (e.g. Ihori, 1996). Since the pollution-generating function is assumed to be quasi-convex, the transfer of capital from a capital abundant country, for example, results in the reduction of the total amount of global public bads.

Now we turn to the welfare effect. The change in revenue may be written as follows:

$$dR^J = -c^g dz + w dv^J - c_w^g dg^J, \tag{19}$$

where the first term of RHS represents the increased cost of global public bads, the second term is an income effect due to the change in factor endowments, and the last term denotes the cost of public input provision. Inserting (18) and $-dv^A = dv^B = d\tau$ into (19), we obtain the welfare effects of the transfer as follows:[9]

$$dR^A = \left(\frac{c^g w_z - w_z c_w^g w}{w_z c_w^g}\right)d\tau + c^g\frac{1-\phi_A^{gB}}{1-\phi_B^{gA}\phi_A^{gB}}\left(h_v^A - h_v^B\right)d\tau, \tag{20}$$

$$dR^B = -\left(\frac{c^g w_z - w_z c_w^g w}{w_z c_w^g}\right)d\tau + c^g\frac{1-\phi_B^{gA}}{1-\phi_A^{gB}\phi_B^{gA}}\left(h_v^A - h_v^B\right)d\tau. \tag{21}$$

In the RHSs of (20) and (21), the first terms, which have the exact opposite effect on income in each country, reflect the change in the factor of production available in the private sector. The second terms represent the worldwide effect of th re-allocation of resources, which have an effect in the same direction.

[8]See Appendix 5.1.
[9]See Appendix 5.1.

The effects of the transfer on welfare depend on which term dominates. In some special cases, either or both terms in the RHSs of (20) and (21) vanish. If the effects of the public bads on production are the same between the two industries in the sense of $\varepsilon \equiv \varepsilon_1 = \varepsilon_2$, then $w_z = -\left(\varepsilon/z\right) w$ holds. Therefore, we obtain,

$$\varepsilon_1 = \varepsilon_2 \Rightarrow \frac{c^g w_z - w_z c_w^g w}{w_z c_w^g} d\tau = 0.$$

In this situation, the amount of global public goods does not affect the relative factor price, w_2/w_1. Furthermore, the primary factors of production available in the private sector do not change. Thus, the transfer is either beneficial or harmful for both countries.

Second, if the factor endowment ratios between the two countries are identical, any infinitesimal change in factor endowment will not affect the total amount of public bads:

$$\frac{v_2^A}{v_1^A} = \frac{v_2^B}{v_1^B} \Rightarrow c^g \frac{1-\phi_B^A}{1-\phi_A^B \phi_B^A} \left(h_v^A - h_v^B\right) d\tau = 0.$$

Hence, the transfer is beneficial for one country but harmful for the other. In particular, depending on the contents of the primary factors of production to be transferred, the transfer may harm the welfare of the recipient country.

It should be noted that a paradoxical result can not be excluded as long as $\varepsilon_1 \neq \varepsilon_2$. The first term in RHS of (21) can be rewritten as follows:[10]

$$-\frac{c^g w_z - w_z c_w^g w}{w_z c_w^g} d\tau = \frac{c^1 c^2}{w_z c_w^g z} \left(\frac{\varepsilon_1 - \varepsilon_2}{\Lambda}\right) \left(c_{w2}^g d\tau_1 - c_{w1}^g d\tau_2\right). \tag{22}$$

From (22), it is shown that if $\left(\varepsilon_1 - \varepsilon_2\right)/\Lambda > (<) 0$ is met, a transfer taking the form of the $v_1(v_2)$ harms the recipient country. For example, let v_1 and v_2 denote labor and capital, respectively, and let ε_1 and ε_2 denote the negative effects on production in the agricultural sector and the manufacturing sector, respectively. Suppose that the agricultural sector is labor-intensive and is affected more by public bads than the manufacturing sector. In this situation, a labor intensive transfer in the sense of $c_{w2}^g/c_{w1}^g > d\tau_2/d\tau_1$ harms the recipient country, while the donor country benefits.

Thus, the effects of the transfer on the welfare can be summarized as follows:

Proposition 3. *Supposing that both governments adopt the clean-up policy,*

(i) If $\varepsilon_1 = \varepsilon_2$ and $v_2^A/v_1^A = v_2^B/v_1^B$ hold, then the level of welfare in each country does not change,

(ii) If $\varepsilon_1 = \varepsilon_2$ and $v_2^A/v_1^A \neq v_2^B/v_1^B$ hold, then the Pareto-improving transfer of factor of production is possible.

(iii) If $\varepsilon_1 \neq \varepsilon_2$ holds, then the transfer paradox may occur.

Together with Proposition 2, Part (i) of Proposition 3 implies that Warr's neutrality theorem is valid if the global public bads symmetrically affect the private sectors of each country and if the factor endowment ratios are identical across countries. Part (ii) of the proposition suggests that the transfer to be Pareto-improving is possible if the factor endowment ratio is vastly different between the two countries. In sum, when the two countries are identical in terms of their factor endowment ratios, the game-theoretic reaction effect dominates the

[10] See Appendix 5.2.

welfare effects of the transfer. In contrast, when the harmful effects resulting from the global public bads are identical across industries, the welfare implication is determined according to the marginal emissions.

3.3 Different Policy Instruments

In our analysis so far, both countries attempt to mitigate the effects of the global public goods using the same policy instrument. In the real world, however, governments adopt different policy instruments. Developing countries may adopt the environmental conservation policy, while developed countries, which have access to advanced technologies in environmental clean-up, may choose to produce public inputs rather than resource conservation.

Our study considers a situation in which two countries adopt different policy instruments in order to reduce global public bads. It is assumed that country A adopts the resource conservation policy while country B produces public input. That is, country A and B's revenue function can be written as (9) and (11), respectively. Non-cooperative equilibrium can be characterized by

$$R_z^A\left(P, h^A + z^{-A}, s_w h^A\right) + w s_w\left(w\right) = 0, \tag{12'}$$

and

$$-R_z^B\left(P, h(v^B) - g^B + z^{-B}, v^B - c_w^g g^B\right) - c^g(w) = 0. \tag{15'}$$

The slope of the optimal response function is given by (14) and (17). In what follows, we consider the transfer of primary factors of production from country A to B. As mentioned in section 2.1, changes in the primary factor of production in country A do not induce any change in welfare and the amount of global public bads. Hence, we consider the change in the factor endowments only in country B.

Differentiating the system consisting (9) and (11), we obtain the change in the total amount of the public bads as follows:

$$dz = \frac{1 + \phi_B^{hA}}{\left(1 + \phi_B^{hA}\phi_A^{gB}\right)\Delta^{gB}}\left(c_w^g w_z h_v^B - w_z\right) dv^B, \tag{23}$$

where $1 + \phi_B^{hA} = s_w w_z / \Delta^{hA} > 0$, $1 + \phi_B^{hA}\phi_A^{gB} > 0$ and $\Delta^{gB} < 0$ follow from second-order and stability conditions.[11] From (23), we can summarize the effects of the changes in the factor endowments on the amount of the global public bads:

Proposition 4. *If the marginal emission by an increase in factor endowments, h_v^B, is sufficiently small, then the amount of global public bads is decreased by the transfer from the country adopting the resource conservation policy to the country adopting the environmental clean-up policy.*

The intuition of Proposition 4 is straightforward. To simplify the explanation, suppose that $\varepsilon_1 = \varepsilon_2 = \varepsilon$. In this case, (23) can be rewritten as follows:

$$dz|_{\varepsilon_1 = \varepsilon_2 = \varepsilon} = \frac{R_z^B h_v^B + w}{R_z^B} dv^B \tag{24}$$

[11] See Appendix 5.3.

Thus, if the net marginal benefit of an increase in the factor endowments, which is represented by $\left(R_z^B h_v^B + w\right) dv^B$, is positive, then the amount of the global public bads is reduced by the transfer.

We now turn to the welfare implications. Noting that $dR^A = R_z^A dz^{-A}$ and $dR^B = R_z^B(h_v^B dv^B + dz^{-B}) + R_v^B dv^B$, and using (23), we obtain the welfare effects as follows:[12]

$$dR^A = \frac{R_z^A}{1+\phi_B^{hA}\phi_A^{hB}} \left\{ \left(1-\phi_A^{gB}\right) h_v^B - \frac{w_z}{\Delta^{gB}} \right\} dv^B, \tag{25}$$

$$dR^B = \frac{R_z^B \phi_B^{hA}}{1+\phi_B^{hA}\phi_A^{gB}} \left\{ \left(1-\phi_A^{gB}\right) h_v^B - \frac{w_z}{\Delta^{gB}} \right\} dv^B + \left(R_z^B h_v^B + R_v^B\right) dv^B. \tag{26}$$

Considering (23), we can write (25) as $dR^A = \left\{R_z^A/(1+\phi_B^{hA})\right\} dz$: in order to improve the welfare of country A, it is necessary that the total amount of the global public goods is reduced. In country B, the welfare effect is more complicated because of the reactive effects of country A. In (26), the first term, which can be rewritten as $R_z^B dz^A$, represents country A's reaction arising from the change in the public bads emitted by country B. This term will be negative if the transfer reduces the total amount of global public bads, and if the slope of the optimal response function of country A is negative. The second term in (26), whose sign depends on the marginal emission of pollution and the unit cost of the public inputs, represents the effects of the change in factor endowments under the constant public bads. Pareto-improving is possible when the unit cost of public inputs in country B, c^g, is sufficiently small.[13]. Hence, we obtain the following proposition:

Proposition 5. *Suppose a transfer from a country adopting the environmental conservation policy to one adopting a clean-up policy. The donor country benefits if the total amount of global public bads are decreased, and the recipient country benefits if the unit cost of abatement is sufficiently small.*

Proposition 5 states the important factor of whether the transfer improves the welfare in the sense of Pareto or not is the technology of the pollution abatement. For example, if the negative effects of public bads on production in the private sector are the same between the two industries, the transfer from country A to country B is Pareto-improving under the condition of $R_z^B h_v^B + w > 0$. That is, for $dv^B > 0$,

$$dR^A\big|_{\varepsilon_1=\varepsilon_2} = \frac{R^A}{R^B}\left(1+\frac{1-\gamma}{1-\varepsilon-\gamma}\right)^{-1} \left(R_z^B h_v^B + w\right) dv^B, \tag{27}$$

$$dR^B\big|_{\varepsilon_1=\varepsilon_2} = \left(1+\frac{1-\gamma}{1-\varepsilon-\gamma}\right)^{-1} \left(R_z^B h_v^B + w\right) dv^B, \tag{28}$$

where $\varepsilon = \varepsilon_1 = \varepsilon_2$ and $\gamma \equiv \varepsilon' z/\varepsilon$.[14] In (27) and (28), since $\phi_I^{gB} = -\phi_I^{hA} = -(1-\gamma)/(1-\gamma-\varepsilon)$ holds, $1+(1-\gamma)/(1-\varepsilon-\gamma) > 0$ follows from the stability conditions. Thus, recalling (24), we can see that Pareto improvement is possible for $dv^B > 0$ if the total amount of the global public bads is reduced by an increase in the factor endowments in country B. Hence, we obtain the following result:

[12] See Appendix 5.3.

[13] Noting that $R_z^B = -c^g$ holds in the equilibrium.

[14] See Appendix 5.4.

Corollary 1. *Suppose that the two countries adopt different environmental policies and that the effects of public bads on production are identical across industries. (i) The transfer of the primary factors of production affects the net revenue of both countries at the same rate:* $dR^A/R^A = dR^B/R^B$ for $dv^B \neq 0$. *(ii) Assistance to the country adopting environmental conservation improves both countries' welfare if the initial abatement cost in the donor country is in the sense of* $\left(R_z^B h_v^B + w\right) dv^B > 0$ *relatively low.*

In the corollary above, $R_z^B h_v^B + w$ represents the marginal effect of an increase in factor endowments on the GDP of country B. Since the change in factor endowments in the country adopting environmental conservation policy does not affect the behavior of that country, the welfare effects depend on the change in factor endowments in the country adopting a clean-up policy.

One might think that the transfer analyzed here differs from a usual assistance for a distributive purpose since this may mean the transfer from developing to developed countries. However, many developed countries support measures for environmental conservation , such as reforestation, in developing countries. Such activities may be interpreted as decreases in the factor endowments available for productive use. Proposition 5 suggests that the assistance for reforestation may be desirable in the sense of Pareto even if the developed country increases gross emissions in exchange for the assistance.

4 Concluding Remarks

This paper has studied the welfare implications of international transfers in the presence of global public bads. In particular, we considered a situation where governments adopt one of two types of policy instruments, namely, environmental conservation or environmental cleanup. Our results show that the welfare effects of assistance depend on the environmental policy that yje government chooses to adopt. When both recipient and donor countries adopt an environmental conservation policy, Shibata's second neutrality theorem is valid. Still, even with an environmental clean-up policy, we cannot exclude the possibility of paradoxical results.

We have also considered a situation in which the two countries adopt different policy instruments. In the real world, developing countries tend to adopt the conservation policy while the developed countries adopt environmental cleanup. Our results suggest that the transfer of factor of production from developing countries to the developed countries that possess advanced clean-up technology could improve the welfare in the sense of Pareto. In contrast, when the unit cost for environmental cleanup is extremely high, the transfer from the developed country engaged in the cleanup policy to the developing country could result in improved welfare under the certain conditions.

The determinants of the effects of the transfer on welfare consist of two parts. The first is the technological aspects of the global public bads and their abatement. The second is a game-theoretic reaction of the governments involved. Our results imply that the reaction effects, which weaken the effectiveness of the transfer, dominate the whole effect when the two countries are similar in factor endowment ratios and adopted policy instruments. In this sense, environmental cooperation, including assistance and transfer, should be pursued between developed and developing countries, rather than solely among developed countries.

In this paper, we concentrated our attention on the small countries facing a fixed commodity price. Our result should ought not vary in a consideration of large countries, as long as the marginal propensities to consume are the same in the two countries. However, if the household preference vary widely, the terms of trade effects will play a significant role.

5 Appendices

5.1 Derivation of (18), (20) and (21)

In a clean-up policy, the initial equilibrium can be characterized by (15). Differentiating and stacking (15), we obtain

$$\Phi^g dg = \Gamma^g dv, \tag{A1}$$

where $dg = [dg^A, dg^B]^T$, $dv = [dv^A, dv^B]^T$,

$$\Phi^g \equiv \begin{bmatrix} \Delta^{gA} & \Delta^{gA} - c_w^g w_z \\ \Delta^{gB} - c_w^g w_z & \Delta^{gB} \end{bmatrix},$$

$$\Gamma^g \equiv \begin{bmatrix} \left(\Delta^{gA} - c_w^g w_z\right) h_v^A + w_z & \left(\Delta^{gA} - c_w^g w_z\right) h_v^B \\ \left(\Delta^{gB} - c_w^g w_z\right) h_v^A & \left(\Delta^{gB} - c_w^g w_z\right) h_v^B + w_z \end{bmatrix},$$

and Δ^{gJ} is defined by (16). Since h_v^J and w_z are two dimensional row vectors, Γ^g is a 2-by-4 matrix. From the stability condition, the sign of determinant of Φ^g must be positive.

$$\det \Phi^g = \Delta^{gA}\Delta^{gB}\left(1 - \phi_B^{gA}\phi_A^{gB}\right) > 0, \tag{A2}$$

where ϕ_I^{gJ} is defined by (17). Solving (A1), we obtain, $dg = [\Phi^g]^{-1}\Gamma^g dv$. After some manipulations, the change in the global public bads is represented by

$$\begin{bmatrix} dg^A \\ dg^B \end{bmatrix} = \frac{1}{1 - \phi_B^{gA}\phi_A^{gB}} \begin{bmatrix} 1 & -\phi_B^{gA} \\ -\phi_A^{gB} & 1 \end{bmatrix} \begin{bmatrix} \phi_B^{gA} h_v^A + \dfrac{w_z}{\Delta^{gA}} & \phi_B^{gA} h_v^B \\ \phi_A^{gB} h_v^A & \phi_A^{gB} h_v^B + \dfrac{w_z}{\Delta^{gB}} \end{bmatrix} \begin{bmatrix} dv^A \\ dv^B \end{bmatrix}. \tag{A3}$$

From (A3), an increase in the factor endowments in one country raises its provision of the public inputs:

$$dg^J = \frac{1}{1 - \phi_B^{gA}\phi_A^{gB}} \left\{ \left(1 - \phi_J^{gI}\right) \phi_I^{gJ} h_v^J + \frac{1}{\Delta^{gJ}} w_z \right\} dv^J, \tag{A4}$$

On the other hand, it is ambiguous whether an increase in the factor endowment in one country raises or reduces the other country's provision of public inputs.

$$dg^J = \frac{\phi_B^{gJ}}{1 - \phi_B^{gA}\phi_A^{gB}} \left\{ \left(1 - \phi_J^{gI}\right) h_v^I - \frac{1}{\Delta^{gI}} w_z \right\} dv^I. \tag{A5}$$

The change in the net amount of public bads generated by each country may be written as follows:

$$\begin{bmatrix} dz^A \\ dz^B \end{bmatrix} = \begin{bmatrix} h_v^A & 0 \\ 0 & h_v^B \end{bmatrix} \begin{bmatrix} dv^A \\ dv^B \end{bmatrix} - \begin{bmatrix} dg^A \\ dg^B \end{bmatrix}.$$

Thus, $dz = dz^A + dz^B$ can be written as follows:

$$dz = \frac{\left(1-\phi_B^{gA}\right)\left(1-\phi_A^{gB}\right)\left(h_v^A dv^A + h_v^B dv^B\right)}{1-\phi_B^{gA}\phi_A^{gB}} - \frac{w_z\left(dv^A + dv^B\right)}{\Delta^{gA}+\Delta^{gB}-c_w^g w_z}. \tag{A6}$$

Inserting $-dv^A = dv^B = d\tau$ into (A6), we obtain (18).

5.2 Derivation of (22)

Recalling that the unit cost functions are homogeneous in w, and using (4), we can write the difference in damages from the global public bads between the industries as follows:

$$\varepsilon_1 - \varepsilon_2 = \frac{-z\Lambda}{c^1c^2}\left(w_2 w_{1z} - w_1 w_{2z}\right) \tag{A7}$$

where $w_{iz} \equiv \partial w_i/\partial z$ for $i = 1,2$. Noting that the term, $c_w^g w$, in (22) is a 2-by-2 matrix and that $c^g = c_{w1}^g w_1 + c_{w2}^g w_2$ follows from the homogeneity of the unit cost function, we can rewrite (22) as follows:

$$\begin{aligned}
\frac{c^g w_z - w_z c_w^g w}{w_z c_w^g} d\tau &= \frac{\left(w_2 w_{1z} - w_1 w_{2z}\right)\left(c_{w2}^g d\tau_1 - c_{w1}^g d\tau_2\right)}{w_z c_w^g} \\
&= -\frac{c^1c^2}{w_z c_w^g z}\left(\frac{\varepsilon_1-\varepsilon_2}{\Lambda}\right)\left(c_{w2}^g d\tau_1 - c_{w1}^g d\tau_2\right),
\end{aligned} \tag{A8}$$

where the last equality is obtained by making use of (A7).

5.3 Derivation of (23), (25) and (26)

When the governments adopt policy instruments that differ from each other, the system can be written by differentiating (12) and (15).

$$\Phi^m \begin{bmatrix} dh^A \\ dg^B \end{bmatrix} = \Gamma^m dv, \tag{A9}$$

where

$$\Phi^m \equiv \begin{bmatrix} \Delta^{hA} & -\left(\Delta^{hA} - s_w w_z\right) \\ -\left(\Delta^{gB} - c_w^g w_z\right) & \Delta^{gB} \end{bmatrix},$$

and

$$\Gamma^m \equiv \begin{bmatrix} 0 & -\left(\Delta^{hA} - s_w w_z\right) h_v^B \\ 0 & \left(\Delta^{gB} - c_w^g\right) h_v^B + w_z \end{bmatrix}.$$

In the equations above, Δ^{hA} and Δ^{gB} are defined in (13) and (16), respectively. The determinant of Φ^m must be positive due to the stability condition of the equilibrium and the second-order conditions:

$$\det \Phi^m = \Delta^{hA}\Delta^{gB}(1 + \phi_B^{hA}\phi_A^{gB}) > 0, \tag{A10}$$

where ϕ_B^{hA} and ϕ_A^{gB} are defined in (14) and (17), respectively. Solving the system, we have,

$$\begin{bmatrix} dh^A \\ dg^B \end{bmatrix} = \frac{1}{1+\phi_B^{hA}\phi_A^{gB}} \begin{bmatrix} \phi_B^{hA}\left\{\left(1-\phi_A^{gB}\right)h_v^B - \frac{w_z}{\Delta^{gB}}\right\} \\ \left(1+\phi_B^{hA}\right)\phi_A^{gB}h_v^B + \frac{w_z}{\Delta^{gB}} \end{bmatrix} dv^B. \tag{A11}$$

Since $z^A = h^A$, the change in the public bads generated in country A can be written as follows:

$$dz^A = \frac{\phi_B^{hA}}{1+\phi_B^{hA}\phi_A^{gB}}\left\{\left(1-\phi_A^{gB}\right)h_v^B - \frac{w_z}{\Delta^{gB}}\right\} dv^B. \tag{A12}$$

In country B, because of $dz^B = h_v^B dv^B - dg^B$, we obtain

$$dz^B = \frac{1}{1+\phi_B^{hA}\phi_A^{gB}}\left\{\left(1-\phi_A^{gB}\right)h_v^B - \frac{w_z}{\Delta^{gB}}\right\} dv^B. \tag{A13}$$

Thus, for an infinitesimal increase in v^B, the amount of the global public bads changes as follows:

$$\begin{aligned} dz &= dz^A + dz^B \\ &= \frac{1+\phi_B^{hA}}{\left(1+\phi_B^{hA}\phi_A^{gB}\right)}\left(\frac{c_w^g w_z h_v^B - w_z}{\Delta^{gB}}\right) dv^B. \end{aligned} \tag{A14}$$

Using (A9) and (A12), we obtain the effects of the transfer on welfare as (25) and (26).

5.4 Derivation of (27) and (28)

Suppose that the negative effects of public bads on production are the same in two private sectors. That is, $a_1(z) = a_2(z)$ and $\varepsilon \equiv \varepsilon_1 = \varepsilon_2$ hold. In this case, (4) can be simplified as $w_z = -(\varepsilon/z)w$. Therefore, we obtain

$$R_z^J\big|_{\varepsilon_1=\varepsilon_2} = -\frac{\varepsilon}{z}wv^{JP} = -\frac{\varepsilon}{z}R^J, \tag{A15}$$

$$R_{zz}^J\big|_{\varepsilon_1=\varepsilon_2} = -\frac{\varepsilon'}{z}R^J - \frac{\varepsilon}{z}R_z^J + \frac{\varepsilon}{z^2}R^J = (1-\gamma+\varepsilon)\frac{\varepsilon}{z^2}R^J, \tag{A16}$$

and $R_{zv}c_{ww}^g w_z g^J = -g^J(\varepsilon/z)^2 w c_{ww}^g w = 0$. Because of $c_w^g w_z = -(\varepsilon/z)c_w^g w = -(\varepsilon/z)c^g$ in the equilibrium, we obtain,

$$c_w^g w_z = \frac{\varepsilon}{z}R_z^J = -\left(\frac{\varepsilon}{z}\right)^2 R^J. \tag{A17}$$

Thus,

$$\phi_I^{hJ}\Big|_{\varepsilon_1=\varepsilon_2} = \frac{1-\gamma}{1-\gamma-\varepsilon}, \tag{A18}$$

$$\phi_I^{gJ}\Big|_{\varepsilon_1=\varepsilon_2} = -\frac{1-\gamma}{1-\gamma-\varepsilon}, \tag{A19}$$

and

$$\Delta^{gJ}\Big|_{\varepsilon_1=\varepsilon_2} = (1-\gamma+\varepsilon)\,\frac{\varepsilon}{z^2}R^J - 2\left(\frac{\varepsilon}{z}\right)^2 R^J \qquad (A20)$$
$$= (1-\gamma-\varepsilon)\,\frac{\varepsilon}{z^2}R^J.$$

Using (A17) -(A20), we obtain (27) and (28).

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